Characteristics of observed surface pressure waves (gravity waves) in the contexts of storm structure and reflectivity features

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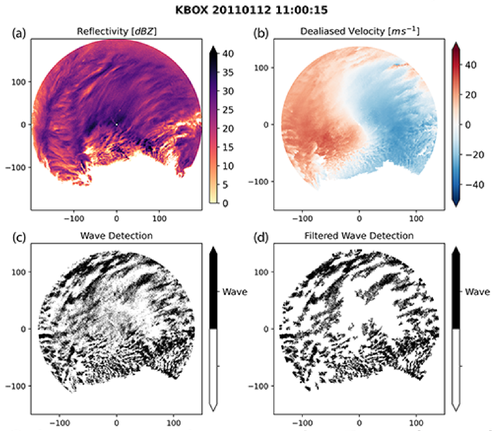
References:

•Hoban, N. P., 2016: *Observed Characteristics of Mesoscale Banding in Coastal Northeast U.S. Snow Storms* (M.S. thesis). North Carolina State University.
•Miller, M. A., et al., 2022: Detecting Wave Features in Doppler Radial Velocity Radar Observations. *Atmos. Meas. Tech.*, doi.org/10.5194/amt-2021-256.
•Allen, L. R., et al., 2023: Objective identification of pressure wave events from networks of 1-Hz, high-precision sensors. *Submitted to Atmos. Meas. Tech.*

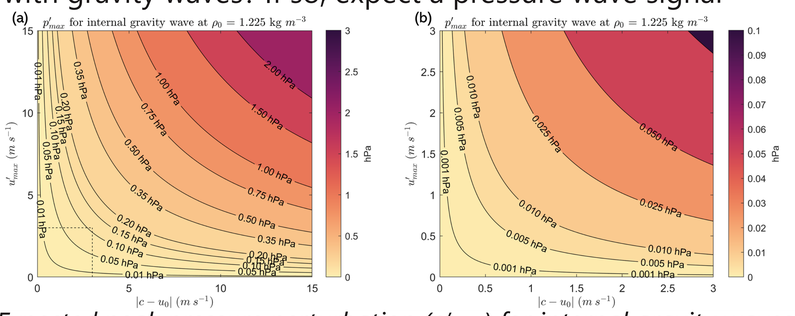
Motivation and Data

- Winter storms frequently have embedded linear enhancements of radar reflectivity / snow rate (*bands*)
- Two band categories can be present together or separately: *primary band* (over 200 km long) and *multibands* (occur in groups; each band is typically less than 100 km long)
- Multibands frequently co-occur with wave features in radar Doppler velocity (*Doppler velocity waves;* Hoban 2016)

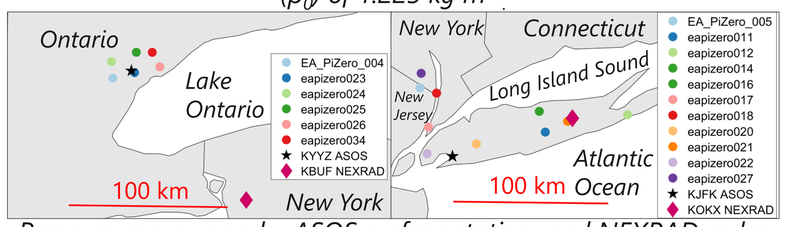


Miller et al. (2022, AMT): Detection of Doppler velocity waves from WSR-88 radar data. Waves are detected using the difference in Doppler radial velocity between successive radar scans.

- Science question: are the Doppler velocity waves associated with gravity waves? If so, expect a pressure wave signal

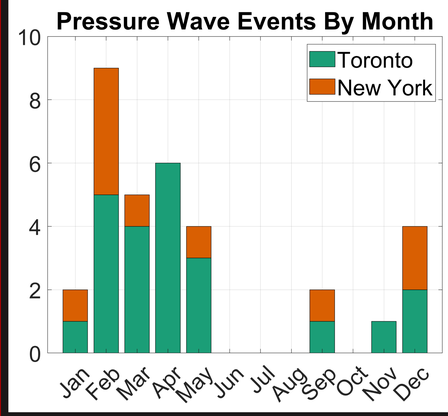


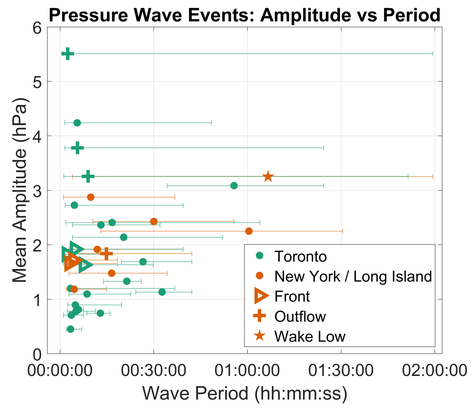
Expected peak pressure perturbation (p'_{max}) for internal gravity waves as a function of the peak wind perturbation (u') and difference between wave phase velocity (c) and mean wind (u_0), for air density (ρ_0) of 1.225 kg m^{-3}

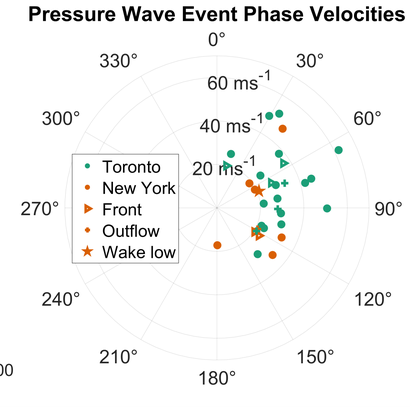


Pressure sensor, nearby ASOS surface station, and NEXRAD radar locations in Toronto (left) and the New York City metro area and Long Island (right). Each pressure sensor records pressure at 1 Hz frequency with a 0.008 hPa noise floor.

Wave Characteristics – January 2020 to April 2023 (28 months)

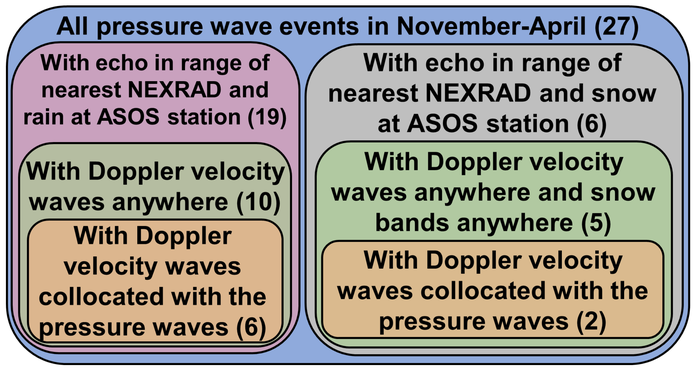




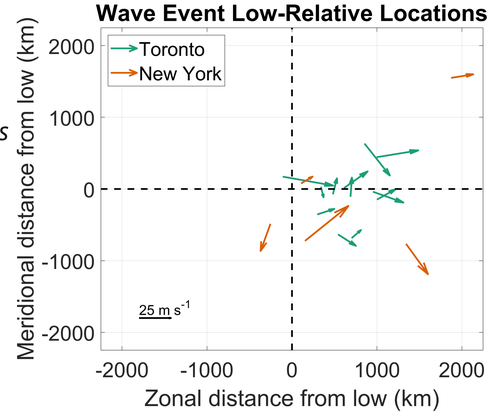


***Left**: number of pressure wave events detected.*
***Center**: wave amplitude and wave period for pressure wave events. Error bars indicate range where normalized wavelet power exceeded 10.*
***Right**: phase speed and direction for pressure wave events which include likely gravity waves (circles), a wake low, and front and outflow passages.*

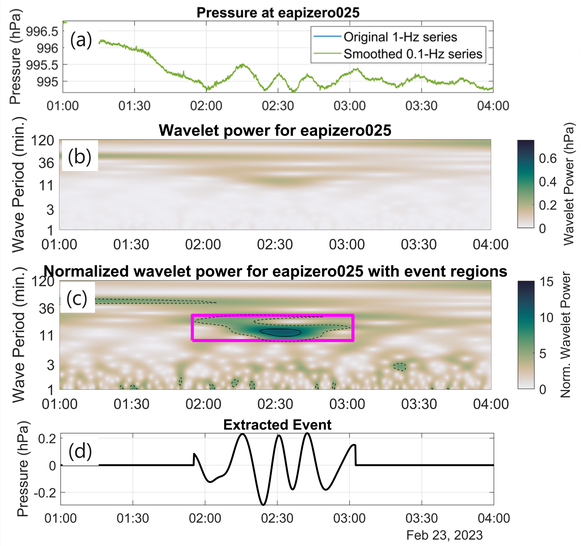
Radar and Storm Context



***Left**: Venn diagram of pressure wave event co-occurrence with radar echo, Doppler velocity waves, and snow bands in Nov-Apr. No pressure wave events were collocated with snow bands.*
***Right**: Pressure wave event locations and phase velocities in framework relative to surface low pressure centers within ERA5 reanalysis. The 17 events shown represent the subset over all months with trackable lows.*



Methods for Detecting Pressure Wave Events



- *Smoothed 1-Hz pressure time series to 0.1 Hz (a)*
- *Calculated wavelet transform (b), then normalized by dividing absolute value of wavelet transform by mean wavelet power at each wave period (c)*
- *Identified peaks over 10 (c, solid contour) and connected regions over 5 (c, dashed contour), then took bounding box as event region (c, magenta box)*
- *Inverted wavelet transform over event region to extract wave event (d) for each sensor separately, then estimated time between wave passages at each pair of sensors using cross-correlation, with a check for whether the maximum cross-correlation exceeded 0.65*
- *Fitted least-squares model to the lag times to get the wave phase velocities. Wave events shown above are those with RMSE< 90 s and normalized RMSE < 0.1 for that fitted model.*
- *More details: Allen et al. (2023, submitted to AMT)*

Findings

- Most detected pressure waves happened during the cool season
- All pressure waves had an eastward component to their phase velocity
- 17 of 25 pressure waves with nearby radar echo were not collocated with Doppler velocity waves
- Most pressure waves occurred to the east of surface lows